PB-213 779

Cost and Supply Analysis for Alum and Methanol Used in Wastewater Treatment

Environmental Protection Agency

AUGUST 1971

Distributed By:

NTIS

National Technical Information Service
U. S. DEPARTMENT OF COMMERCE
5285 Port Royal Road, Springfield Va. 22151

PB 213 779

COST AND SUPPLY ANALYSIS FOR ALUM AND METHANOL USED IN WASTEWATER TREATMENT

by

Robert Smith
Walter F. McMichael

Reproduced by
NATIONAL TECHNICAL
INFORMATION SERVICE
U S Department of Commerce
Springfield VA 22151

ENVIRONMENTAL PROTECTION AGENCY
Office of Research and Monitoring
Advanced Waste Treatment Research Laboratory
Cincinnati, Ohio

August 1971

TABLE OF CONTENTS

CONCLUSIONS

POTENTIAL DEMAND FOR ALUM AND METHANOL FOR WASTEWATER TREATMENT

CURRENT CONSUMPTION AND POTENTIAL PRODUCTION CAPACITY

RESOURCES OF RAW MATERIALS

CURRENT MARKET PRICE AND COST PROJECTION

POTENTIAL IMPACT ON TRANSPORTATION INDUSTRY

INVENTORIES REQUIRED AT THE WASTEWATER TREATMENT PLANT

REFERENCES

CONCLUSIONS

The use of alum for phosphorus removal and methanol for nitrogen removal from municipal wastewaters in the United States is not likely to have a profound impact on manufacturing capability, resources of raw material, or the transportation industry. Additional manufacturing facilities for both alum and methanol would be required if a major fraction of the wastewater from the urban population of the U.S. is to be treated for phosphorus and nitrogen removal but no significant demand on the raw materials resources or the transportation industry is anticipated.

POTENTIAL DEMAND FOR ALUM AND METHANOL FOR WASTEWATER TREATMENT

The goal of EPA has been to promote adequate treatment of wastewater for the entire urban population of the United States. The urban population of the U.S. in 1970 was 149,280,769. The projected urban population for 1976, which will be taken as the target date for installation of treatment facilities for removal of nitrogen and phosphorus, is about 170 million persons.

The commonly recommended dose of alum to be added to the final settler of the activated sludge process for precipitation of phosphorus is 1.5 moles of aluminum per mole of phosphorus present in the feed stream. If we assume that each person produces 100 gallons of wastewater per day and the concentration of phosphorus in the feed stream is 10 mg/l, the required dose of dry alum ($Al_2(SO_4)_3 \cdot 14H_2O$) corresponds to 43.8 pounds per person per year. If every person in the urban population in 1976 used 43.8 pounds of dry alum per year, the total annual consumption would be 3,723. thousand tons.

Methanol (CH_3OH) is used in the denitrification process for the removal of nitrogen from wastewater. The methanol dose generally quoted is 3 mg/l of methanol per mg/l of nitrate nitrogen. In normal municipal wastewater the concentration of nitrate nitrogen following the nitrification process is about 20 mg/l. Thus, a dose of 60 mg/l of methanol will be required. If we assume the

standard 100 gallons per day per person for wastewater volume, the yearly consumption of methanol will be 18.25 pounds per capita per year. Using the projected urban population for 1976 of 170 million persons the national requirement for methanol in wastewater treatment plants would be 3,103 million pounds per year.

The amount of wastewater which is discharged into lakes or streams where eutrophication might be a problem is not known with any precision. We know that municipal discharges requiring removal of nitrogen and phosphorus will be some fraction of the total municipal wastewater. Industrial wastewater treatment might also demand quantities of these chemicals but no adequate inventory of industrial wastes exists at this time.

Professor Dan Okun of the University of North Carolina in testimony before the Federal Trade Commission estimated that 55% of the population discharges its wastewater into the oceans or large rivers where no problem of eutrophication exists. He estimated that another 30% of the population is served by septic tanks or individual treatment units which present no problem. The remaining 15%, therefore, represents the population which discharges to lakes or streams where eutrophication might be a problem and where phosphorus and nitrogen removal might be required. The population of the U.S. in 1970 was about 203 million. Fifteen percent of this value is 30.45 million. This represents about 20% of the

urban population in 1970. This is generally believed to be a low estimate by others working in the field. Since no accurate estimate of the amount of wastewater which will require phosphorus and nitrogen removal is available, in the following sections of this report it will be assumed that wastewater from all of the 170 million urban population will require removal of nutrients by 1976. It should be realized, however, that these estimates are probably too large by a factor of at least two.

CURRENT CONSUMPTION AND POTENTIAL PRODUCTION CAPACITY

Since 1940 the consumption of dry alum ($Al_2(SO_4)_3 \cdot 14H_2O$) in the United States has increased consistently by about 3.51% per year. In 1969 the apparent consumption of dry alum was 1,323 thousand short tons. All tonnages are given as short tons (2000 lbs). Alum produced in 1969 was 1,320 thousand tons. A negligable fifteen thousand tons were imported and twelve thousand tons exported in 1969. In 1969 the amount used in water treatment was about 425 thousand tons or about 32% of the total consumption. The estimated consumption of dry alum in the pulp and paper industry was 860 thousand tons in 1969. The capacity for production of alum in the United States as of January, 1971 has been estimated as 1716 thousand tons per year. The production of 1320 thousand tons in 1969, therefore, represented about 77% of total capacity. Since 1958, the production capacity has increased an average of only 1.26% per year while the consumption has increased by 3.51% per year. If this trend continues, the consumption will equal the plant capacity at about 1980.

The present production capacity is, therefore, about 50% of the estimated demand for alum assuming that the entire 1976 urban population will require wastewater treatment for removal of nutrients.

Technology for the production of alum is well established and there is no known deterrent to building additional manufacturing facilities if the need exists. Alum is produced from bauxite or clays found in Arkansas, Alabama, and Missouri or imported, chiefly from Jamaica and Surinan. In 1969 2064 thousand tons of bauxite was mined in the U.S. while 13,642 thousand tons were imported. The total consumption of bauxite in the U.S. was 17,450 thousand tons.

The manufacturing process involves digesting the bauxite with sulfuric acid, removing solids by sedimentation and treating the solution to precipitate iron compounds until sufficiently low iron content is obtained. The resulting liquid alum is about 8.3% alumina (Al_2O_3). Dry alum is produced by evaporating the water from the liquid alum until the resulting white or cream colored powder is 17.1% alumina.

Bauxite is generally classified as Jamaican, Surinam, or European. Each of the ores contain about 50% alumina. In the production of one ton of dry alum 670 pounds of bauxite and 1140 pounds of sulfuric acid are used. The equivalent amount of sulfur for production of sulfuric acid is 373 pounds. On this basis the amount of bauxite used for production of the 1320 thousand tons of alum in 1969 was about 442 thousand tons or about 2.5% of the total consumption of bauxite in the U.S. in 1969. Actually,

roughly one third of the alum is produced from clays mined in the U.S.

In 1965 the use of sulfuric acid and sulfur trioxide in the U.S. totaled 25,700 thousand tons. Of this total, 580 thousand tons or 2.3% was used in the production of alum.

If the production of alum continues to increase at 3.51% per year the expected production in 1976, if no alum is used for wastewater treatment, would be about 1.68 million tons. If alum addition for wastewater treatment were installed for the total urban population, the production would jump from 1.68 million tons to 5.40 million tons per year. To meet this demand on an equal percentage increase per year basis the production of alum would have to increase by about 31% per year between 1971 and 1976. In computing this estimate it was assumed that between 1969 and 1971 the average increase in production was 3.51%. This kind of an increase is apparently well within the capabilities of the industry.

According to a spokesman for Allied Chemical Corp. the Allied North Claymont, Delaware alum plant has existing capacity to meet the needs of Washington, D.C. in 1972 and 1973 and with some modification in raw material handling this plant can meet the 1980 requirement

of 80,000 tons. If necessary, the back-up could be supplied from existing excess capacity at the Hopewell, Virginia plant or the Covington, Virginia plant.

Between 1960 and 1970 U.S. methanol production grew at an average rate of over 9.5% per year. Total production of methanol in the U.S. in 1970 was 4,944.5 million pounds. Most of this production was used within the producing company for production of other industrial chemicals. The reported sales in 1968 was 1,490.4 million pounds as compared to a total production of 3,817.4. This corresponds to a sales to production ratio of 0.39.

As of January 1, 1971, eleven companies were producing methanol and their total capacity was 6,875 million pounds per year. The ratio of production to production capacity was, therefore, about 72%. In addition to this, if all announced plant expansions come on stream as scheduled, methanol capacity will increase to 8,864 million pounds per year by January 1, 1972. This represents a planned increase of 28% in production capacity in one year.

If it is assumed that the 3,103 million pounds of methanol needed for water pollution control is added to the normal usage increasing at 9.5% per year, the amount required in 1976 would be 8,523 million pounds for normal usage plus the 3,013 million pounds

needed for water pollution control for a total of 11,626 million pounds per year in 1976. This would correspond to an average required increase in consumption of 16.5% per year instead of the normal 9.5% per year.

Since the production capacity of methanol producing plants was increased by 28% per year between 1971 and 1972, the 16.5% increase in demand will probably not be difficult to attain.

Essentially all methanol manufactured in the U.S. is based on the use of natural gas. Since natural gas contains more than the ideal amount of hydrogen, carbon dioxide is usually added to the feed to balance the excess hydrogen. In order to assure adequate supply of carbon dioxide, methanol producers are often located near ammonia producing plants since carbon dioxide is produced as a waste in the production of ammonia.

Natural gas is 67% carbon and 22% hydrogen by weight while methanol is 37.5% carbon and 12.5% hydrogen by weight. Based on simple mass balance relationships one pound of methanol requires 0.568 pounds of natural gas. Assuming 60% recovery, 0.95 lb of natural gas will produce one pound of methanol. Thus, in 1970 when 4,945 million pounds of methanol were produced, the consumption of natural gas must have been approximately 4,700

million pounds. Since natural gas weighs 0.046 pounds per standard cubic foot, this is equivalent to about 102 billion scf per year.

The latest value for consumption of natural gas in the U.S. was 20.9 trillion scf in 1969. Thus, the gas used for production of methanol represents about 0.50% of the total consumption. Clearly, this is not an important fraction of the total consumption of natural gas.

If the production of methanol is increased to provide for nitrogen removal in all urban communities in 1976, the fraction of the total consumption of natural gas used for methanol production can be expected to jump from 0.71% to 0.97%.

RESOURCES OF RAW MATERIALS

The two principal raw materials used in the production of alum are bauxite ore or aluminum bearing clay and sulfuric acid. The active ingredient in alum for wastewater treatment is aluminum. The amount of aluminum which would be used for wastewater treatment assuming an urban population of 170 million, 100 gallons of wastewater per person and ten mg/l of phosphorus in the wastewater would be about 0.338 million tons per year.

The apparent consumption of all forms of aluminum in 1968 was about 4.71 million tons. Of this total about 0.16 million tons or 3.4% was used in the production of chemicals. About 92% of all aluminum consumed was in the form of metal. Between 1970 and 2000 the demand for aluminum metal is expected to increase at a rate of between 5.1% and 7.4% per year. The demand for nonmetal forms of aluminum is expected to increase at a rate between 3.5% and 5.8% per year between 1970 and 2000. The total consumption of aluminum in all forms would then fall between 22.4 and 44.4 million tons per year in the year 2000. It has been estimated that by the year 2000 the consumption of aluminum in chemicals and allied products will be between 0.5 and 1.0 million tons per year.

KNOWN RESERVES OF BAUXITE IN THE WORLD

	Bauxite[1]	Aluminum equivalent[2]
North America:		
United States:		
Arkansas	44	8.8
Southeastern States	1	.2
Total	45	9.0
Caribbean Islands:		
Dominican Republic & Haiti	85	17.0
Jamaica	600	120.0
Total	685	137.0
South America:		
Brazil	40	8.0
Guyana	80	16.0
French Guiana	70	14.0
Surinam	200	40.0
Total	390	78.0
Europe:		
Austria	1	0.2
France	70	14.0
Greece	84	16.8
Hungary	150	30.0
Italy	24	4.8
Rumania	20	4.0
Spain	7	1.4
U.S.S.R. (including Soviet Asia)	300	60.0
Yugoslavia	200	40.0
Total	856	171.2
Africa:		
Ghana	290	58.0
Guinea	1,200	240.0
Mozambique	2	0.4
Malawi	60	12.0
Sierra Leone	30	6.0
Total	1,582	316.4
Asia:		
China, mainland	150	30.0
India	64	12.8
Indonesia	20	4.0
Malaysia:		
Peninsular Malaysia	10	2.0
Sarawak	5	1.0
Turkey	30	6.0
Total	279	55.8
Oceania:		
Australia	2,000	400.0
Palau Islands	5	1.0
Total	2,005	401.0
Total for world	5,842	1,168.4

[1]Millions of metric or long tons (2240 lbs)

[2]Millions of short tons (2000 lbs)

Source: U.S. Bureau of Mines, Mineral Facts and Problems, 1970, 1970 Edition, U.S. Government Printing Office, Washington, D.C.

TABLE 1

Using the predicted rates of increase for aluminum the mean demand for aluminum in 1976 should be about 7.6 million tons. Thus the 0.338 million tons used for wastewater treatment would represent about 4.4% of the total aluminum consumed in 1976.

The total amount of bauxite consumed in the U.S. in 1969 was 17,450 thousand tons. Of this 2,064 thousand tons or about 11% was mined in the United States. Known resources of bauxite in the U.S. and the rest of the world are shown in Table 1. It is doubtful if the United States can continue to supply approximately 10% of its future needs for aluminum. Technology to more economically recover aluminum from domestic clays is needed.

In addition to the reserve of commercial-grade bauxite, potential sources of aluminum of almost unlimited size occur in the United States, which must wait for new—and in some instances, revolutionary—technologies, as well as higher prices, to be processed profitably for aluminum. Potential sources of aluminum in the United States include the large low-grade bauxitic clay deposits in Arkansas (65 million tons); low-grade gibbsitic bauxite containing substantial amounts of kaolinite in Alabama and Georgia (25 million tons); low-grade ferruginous bauxite deposits of Oregon and Washington (85 million tons); and low-grade bauxite in Hawaii (125 million tons). The total potential resource of bauxite in the United States is approximately 300

million long tons. Information on other potential sources of aluminum occurring in ferruginous bauxite, bauxitic clay, kaolin and other types of clay, anorthosite, the kyanite group of minerals, laterites, and shales, averaging 27 to 42 percent Al_2O_3, has been compiled by the Bureau of Mines.

The United States is the world's largest consumer of sulfur. In 1968 the U.S. consumed about 26% of the world consumption of sulfur. In 1969 the consumption of all forms of sulfur in the U.S. was 10,276 thousand tons. World production of sulfur in 1968 is shown in Table 2. About one-half of this total was used in the manufacture of fertilizers. About 87% of the sulfur consumed in the U.S. is in the form of sulfuric acid, 11% is elemental sulfur, and 2% as hydrogen sulfide and sulfur dioxide. In 1965 25,700 thousand tons of sulfuric acid and sulfur trioxide were used and 580 thousand tons or 2.3% of this was used for the production of alum.

Estimates of the sulfur resources in the U.S. are shown in Table 3. Known reserves of sulfur in the world are shown in Table 4.

In addition to this, the prospect of removing sulfur dioxide from the stack gas of electric utilities and other industries as an air pollution control measure would make huge quantities of

WORLD SULFUR PRODUCTION BY COUNTRY AND TYPE, 1968

(Thousand long tons, sulfur)

Country	Ores	Frasch	Recovered	Smelter Acid	Pyrites	Other	Total
United States	2	7,458	1,474	430	362	91	9,817
U.S.S.R.[e]	1,033	-----	443	(1)	1,824	300	3,600
Japan[e]	256	-----	74	(1)	1,870	500	2,700
Canada[e]	-----	-----	3,108	350	142	-----	3,600
France[e]	-----	-----	1,589	(1)	33	148	1,770
Mexico	24	1,582	52	(1)	-----	42	1,700
Poland[e]	507	788	-----	(1)	90	140	1,525
Spain[e]	-----	-----	39	(1)	1,136	50	1,225
China, mainland[e]	118	-----	128	(1)	669	285	1,200
Italy	90	-----	2	(1)	623	172	887
Germany, West	-----	-----	125	(1)	248	266	639
Finland[e]	-----	-----	108	(1)	365	152	625
Others[e]	300	-----	350	(1)	2,500	2,862	6,012
Total	2,330	9,828	7,492	780	9,862	5,008	35,300

[e]Estimate

(1) Combined with other

Source: U.S. Bureau of Mines, Mineral Facts and Problems, 1970, 1970 Edition, U.S. Government Printing Office, Washington, D.C.

TABLE 2

ESTIMATED SULFUR RESOURCES IN THE UNITED STATES

Source	Sulfur (million long tons)
Native sulfur	530
Pyrite	250
Sulfide ores (smelters)	50
Natural gas	50
Petroleum	50
Oil shale	1,500
Coal	13,000
Anhydrite and gypsum	18,500
Sea water	NA

NA Not available

Source: U.S. Bureau of Mines, Mineral Facts and Problems, 1970, 1970 Edition, U.S. Government Printing Office, Washington, D.C.

TABLE 3

APPARENT RESERVES OF SULFUR IN THE WORLD

(Million long tons)

Area	Petroleum	Natural gas	Native ore	Dome	Sulfide ore	Pyrite	Total
United States	30	25	100	100	25	25	305
Canada	5	100	(1)	---	25	25	155
Mexico	5	(1)	(1)	50	10	5	70
Central and South America	30	(1)	100	---	50	50	230
West Europe	(1)	25	5	---	5	25	60
East Europe	20	20	100	---	100	150	390
Africa	5	(1)	(1)	---	20	20	45
Near East and South Asia	340	500	200	---	5	50	1,095
Far East and South East Asia	10	10	50	---	20	20	110
Oceania	---	---	(1)	---	5	5	10
Total	445	680	555	150	265	375	2,470

(1) Insignificant

Source: U.S. Bureau of Mines, Mineral Facts and Problems, 1970, 1970 Edition, U.S. Government Printing Office, Washington, D.C.

TABLE 4

sulfur available and perhaps drive the price down. For example, in electric utilities alone about 295 million tons of soft coal were burned in 1968. If we take the average sulfur content of soft coal as 3%, this is equivalent to 8.84 million tons of sulfur which could be removed from the stack gas. Since about 694 thousand tons of sulfur would be needed to produce the required 3,723 thousand tons of alum, less than 10% of the sulfur recovered from the stack gases would satisfy the alum production need.

Sulfur was in short supply in the 1963-67 period and the price of sulfur peaked at about $42 per long ton. One long ton equals 2240 pounds. After production facilities adjusted to meet the demand in 1968, the price of sulfur began to drop. The current price for sulfur is $26-$27 per long ton and no shortage exists.

Natural gas is the principal ingredient in the production of methanol. It has been computed that 3,103 million pounds of methanol would be needed to treat all of the municipal wastewater in 1976. Assuming 60% recovery for the natural gas this amount is equivalent to about 64 billion scf of natural gas. In 1968 the total consumption of natural gas in the U.S. was 19.46 trillion cubic feet. Of this total about 13.2% or 1.2

trillion cubic feet were used in the chemicals and allied products industry. The nonfuel use of natural gas is expected to increase at an average rate of 4 to 6 percent between 1970 and 2000. Thus, about 1.77 trillion cubic feet of gas is expected to be used in the manufacture of chemicals in 1976. The production of methanol for wastewater treatment would represent about 3.6% of the amount used for the production of all chemicals.

Known resources of natural gas in the United States total 287.35 trillion cubic feet. Known resources in the world total 1,144 trillion cubic feet. It is believed that actual deposits of natural gas in the U.S. exceed the known resources by a large factor. For example, the U.S. Geological Survey estimates remaining natural gas resources as 2,400 trillion cubic feet. An estimate made by the Potential Gas Committee was less optimistic. Their estimate was 1,227 trillion cubic feet for available undiscovered resources. The use of natural gas in the U.S. between 1970 and 2000 is expected to increase by 2.4% per year. On this basis, the average consumption in 2000 would be 45.3 trillion cubic feet. The cumulative demand over this period (1970-2000) is between 860 and 1,130 trillion cubic feet. Estimated remaining recoverable resources are, therefore, about sufficient for the needs between now and 2000.

In 1968 a total of 5.605 million tons of phosphorus in the form of phosphate rock was produced in the United States. This represents 45% of the total world output. In 1968 3.475 million tons of phosphorus were consumed in the United States. Of this total 2.65 million tons were used for fertilizer. An estimated 250 thousand tons were used in the soap and detergent industry.

In 1968 approximately 25.8 pounds of phosphorus in fertilizer was used per person. Since 1950 the per capita use of fertilizer has increased by an average of 4% per year. By the year 2000 it is estimated that at least 40 pounds of fertilizer phosphorus will be used per capita per year.

At this rate of increase we can estimate that by 1976 about 35 pounds of fertilizer phosphorus will be used per capita per year. If wastewater contains ten mg/l phosphorus and we assume 100 gallons per day per person, the phosphorus available in municipal wastewater will equal about 3 pounds per capita per year. This represents only about 10% of the amount normally used for fertilizer. The reserves of phosphate rock in the U.S. and the rest of the world are shown in Table 5.

Thus, the known resources of phosphorus in phosphate rock are adequate for about one thousand years.

KNOWN AND POTENTIAL RESERVES OF PHOSPHATE ROCK AND APATITE IN THE WORLD

Country	P content, million short tons	Estimated grade, percent P
Morocco	9,220	14
United States	6,800	10
Tunisia	900	13
Algeria	400	12
Other free world	1,000	11
U.S.S.R.	2,600	9
Mainland China and North Vietnam	900	11
Total	21,800	..

Source: U.S. Bureau of Mines, Mineral Facts and Problems, 1970, 1970 Edition, U.S. Government Printing Office, Washington, D.C.

TABLE 5

CURRENT MARKET PRICE AND COST PROJECTION

Alum can be supplied in liquid or dry form. Dry alum is about 17.1% alumina and liquid alum is about 8.3% alumina. Thus, liquid alum is about 50% water and 50% dry alum. The cost of liquid and dry alum at the plant is relatively stable. The cost of liquid alum on a 17.1% alumina basis ranges between $43 per ton and $47 per ton. The cost of dry alum (17.1% alumina) ranges between $62 per ton and $63.50 per ton in 100 lb bags. The cost of bulk alum is slightly less; about $58-$62 per ton.

The cost of transportation by truck is highly variable and depends strongly on the exact route and the region of the country. On a dry alum basis (17.1% alumina) the cost of transportation for both liquid and dry alum ranges between $4 and $14 per ton when the hauling distance is between ten and one hundred and ten miles. There is some dependency on distance but unless the exact locations of the alum plant and the delivery point are know the transportation cost cannot be estimated with any precision. This conclusion is based on the known cost of hauling dry and liquid alum over about forty specific routes.

About sixty-one alum producing plants are located east of the Mississippi River. About seventeen plants are located west of the Mississippi River. From a map showing the location of all

alum producing plants in the U.S. it can be concluded that any point east of the Mississippi can be reached by hauling 200 miles or less. West of the Mississippi, the maximum hauling distance is roughly 550 miles. Because of the difficulty in estimating trucking rates, however, it is impossible to estimate the maximum hauling cost in any reliable way.

Most of the plants for production of methanol are in Texas and Louisiana but the price is relatively independent of the delivery point. For example, in August, 1971, the E.I. du Pont de Nemours and Co., Inc. quoted only two prices for methanol delivered. For Texas and states east of Texas the price delivered was 25 cents per gallon. For states west of Texas the price was 27 cents per gallon.

The price index for industrial chemicals increased from 58.1 in 1940 to a peak of 100.5 in 1960. By 1965 it had dropped to a relatively stable 95. The price of dry alum has approximately followed this trend except that since 1963 the price has continued to increase. The price in 1963 was $40 per ton and the present price is about $62 per ton. Methanol, on the other hand, has steadily declined in price since 1930. In 1930 the price was 40 cents per gallon. The minimum price was 24 cents per gallon in 1945-48. The present price is 25 cents per gallon. When we realize that the wholesale purchasing power of the dollar

has decreased from $2.37 in 1939 to 92 cents in 1968, this decrease in the actual price of methanol represents a significant improvement in the technology for producing methanol.

The only factor which might contribute to increased prices for alum is the fact that most of the bauxite now used in the U.S. is mined in South America. If nationalization of these resources should occur with a resulting shortage of high quality bauxite, clays native to the U.S. might be used for the production of alum as well as aluminum metal. This could result in a significant increase in price for alum. No shortage of sulfur or sulfuric acid is anticipated. As a matter of fact, the price of sulfur has steadily declined since 1965.

Since methanol is produced principally from natural gas and represents only a small fraction of the amount of natural gas used for fuel, there is no reason to expect the price of methanol to increase due to a shortage of natural gas through the year 2000.

POTENTIAL IMPACT ON TRANSPORTATION INDUSTRY

In 1968 it was reported by the Interstate Commerce Commission that motor carriers delivered a total of 17.2 million truckloads weighing 309 million tons. Of this total chemical and allied products accounted for 1.975 million truckloads and petroleum and coal products including motor fuel accounting for 4.267 million truckloads.

One gallon of liquid alum contains about 5.4 pounds of dry alum. One 5000 gallon tank truck can, therefore, transport about 13.5 tons of dry alum. Since the maximum amount of dry alum needed for wastewater treatment has been estimated as 3.723 million tons, the equivalent number of truckloads would be about 275,800.

One gallon of methanol weighs about 6.63 pounds. One 5000 gallon truck can, therefore, transport about 16.6 tons of methanol. The maximum national requirement for methanol has been estimated as 3,103 million pounds. This is equivalent to 1.5515 million tons or 93,464 truckloads. For both liquid alum and methanol the maximum number of truckloads is, therefore, 0.369 million. This number of truckloads represents about 2% of the total for 1968 and about 18.6% of the chemical and allied products total.

Although this amount of transportation for alum and methanol would represent a significant increase in tonnage for the chemicals and allied products category, the impact on the whole trucking industry would be minimal.

INVENTORIES OF CHEMICALS REQUIRED AT THE WASTEWATER TREATMENT PLANT

Liquid alum or methanol can be shipped in railroad tank cars with a capacity of 8,000 to 18,000 gallons or in tank trailers with a capacity of 3,000-5,000 gallons. Liquid alum is corrosive and the container must be made of stainless steel or rubber lined. The recommended storage capacity at the treatment plant is 150% of the volume of the tank truck or tank car or ten days supply which ever is greater. Liquid alum begins to crystallize at 30°F and freezes at about 18°F. Storage tanks must, therefore, either be located indoors or provided with heating coils to maintain the temperature above 45°F. Underground storage might be used for liquid alum.

The amount of dry alum used in treating wastewater with 10 mg/l of phosphorus is about 1200 lb/day/mgd. Since one gallon of liquid alum contains 5.4 pounds of dry alum, this is equivalent to about 222 gal./day/mgd. When a tank trailer is to be used for delivery of liquid alum, the minimum size storage tank would be 7,500 gallons. This corresponds to ten days supply for a plant of about 34 mgd capacity. Thus, the storage capacity at a 50 mgd plant for liquid alum would be about 11,000 gallons and for 100 mgd, 22,000 gallons.

Dry alum can be delivered in 100 lb bags or in bulk with a minimum delivered weight of 40,000 pounds. It is anticipated that because of the ease of handling liquid alum, the liquid form would be used in all but the smallest plants. For example, in a one mgd plant about twelve 100 lb. bags would be required each day. The density of dry alum ranges between 38-45 pounds per cubic foot for powdered alum to 57-61 pounds per cubic foot for rice alum.

Methanol can be stored in plain steel tanks. Rust may form however, from atmospheric moisture entering the tank. If plain steel equipment is used, a fine porosity filter to remove rust particles should be installed. Aluminum is attacked by methanol and is, therefore, unsuitable. Baked-phenolic-lined tanks or stainless steel tanks are preferred. Methanol has a flash point of 58^{o}F and underground storage is, therefore, suggested. Dry nitrogen can be used to fill the vapor space in the tanks. Dry nitrogen not only limits the flammability hazards but also minimizes the moisture pick-up during storage. Piping and pumps should be of the same metal as the tank. Centrifugal pumps with explosion-proof electric motor drives are recommended.

The minimum storage required for methanol is 150% of the volume of the tank truck or rail car or ten days supply. The nominal use of methanol in a one mgd plant is 500 lb/day or 75.4 gallons per day. A ten day supply would be 754 gallons; thus, for plants greater than 10 mgd the size of the storage facility would be larger than 7,500 gallons. Storage for a 100 mgd plant would be 75,400 gallons.

REFERENCES

"Minerals Yearbook", Volume I-II, Metals, Minerals, and Fuels, U.S. Dept. of Interior, Bureau of Mines (1969).

"Mineral Facts and Problems", 1970 Bureau of Mines Bulletin 650, U.S. Dept. of Interior (1970).

"Chemical Economics Handbook", Stanford Research Institute, Menlo Park, California.

"Kirk-O'Thimer Encyclopedia of Chemical Technology", Volume 13, (1967)

1970 Statistical Abstract

"Freight Commodity Statistics—Year Ended December 31, 1968", Bureau of Accounts, Interstate Commerce Commission (1968)